Significant Wave Height Comparisons Between TOPEX and Platform Harvest

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Abstract

Two sources of $H_{1/3}$ estimates were available at Platform Harvest; a NOAA buoy and CU depth sensor highrate data. $H_{1/3}$ estimates from the NOAA buoy were based on twenty minutes of data every hour, CU pressure measurements were taken every 1.1 seconds. For purposes of this paper, $H_{1/3}$ estimates from the CU depth sensor were based on one hour of data, This paper compares $H_{1/3}$ measurements from TOPEX with each of these sources, Differences between $H_{1/3}$ estimates from the CU depth sensors based on twenty minutes and estimates based on one hour of data varied by up to 10% with an rms uncertainty of $\pm 5\%$. There is an rms difference between the NOAA buoy and altimeter values of O. 17m with a mean offset of 0.03m such that the $H_{1/3}$ values from the altimeter are higher than from the buoy. There is an rms difference between the CU values and altimeter values of O. 19m with a mean offset of O. 1m such that the $H_{1/3}$ values from the altimeter are higher than from the CU depth sensors. This strongly suggests that the $H_{1/3}$ measurements from the TOPEX altimeter are well within project specifications

1. Introduction

Prior to 1975, the statistical study of wave heights was limited to coastal buoys and ship reports. With the advent of satellite altimetry, it became possible to monitor $H_{1/3}$ (or significant wave height) from space. Beginning with GEOS-3 (1975-78), global monitoring of $H_{1/3}$ became a reality and resulted in the first global atlas of significant wave height derived from satellite observations (McMillan, 1981). GEOS-3 was followed SeaSat (1978), GEOSAT (1985-1989), ERS-1 (1991 - present) and TOPEX/Poseidon (1992 - present).

$H_{1/3}$ is defined to be the average of the highest one third of the waves (as measured peak to trough) in a region or time period, Satellite altimeters estimate this quantity by the slope of the leading edge of the return pulse (Brown, 1977). The standard $H_{1/3}$ accuracy requirement for recent radar altimeter missions has been 0.5 meters (m) or ten percent, whichever is larger.

$H_{1/3}$, as estimated from satellite altimeter measurements, has been previously compared with buoy observations (McMillan, 1981; Dobson, et al, 1987; and Monaldo, 1988, Carter et al., 1992). In general, the satellite did not directly overfly these buoy sites. This resulted in an error term because the satellite and buoy were not measuring precisely the same wave field (Monaldo, 1988 and Dobson et al., 1987), In this paper, we evaluate $H_{1/3}$ estimates from the NASA altimeter on the TO PEX/Poseidon satellite as it directly overflies the NASA verification site.

In addition to buoy-derived $H_{1/3}$ values, significant wave height has been also calculated from high-rate sea level data obtained from submerged pressure measurements. These high-rate data permit us to investigate the variation of $H_{1/3}$ with the amount of data used, We start by discussing the sources of the data, the variation of $H_{1/3}$ with time, the $H_{1/3}$ environment at Platform Harvest, and finally comparisons with measurements from the TOPEX altimeter.

Sources of Data

The TOPEX/Poseidon satellite overflies the NASA verification site, Texaco's Platform Harvest located 19.5 kilmeters (km) west of Point Conception, California, once every 9.9 days. An overview of the instrumentation at Platform Harvest is given in Morris, et al., this issue, The satellite is maintained in an orbit such that the groundtrack always passes within one kilometer of the platform; thus providing an excellent point of comparison. The $H_{1/3}$ estimates from the NASA altimeter were obtained from the one second TOPEX Geophysical Data Records (GDR). The data quality flags on the GDR data records near the platform were checked to insure that the $H_{1/3}$ estimates were valid. The one-second $H_{1/3}$ values were then interpolated to the time of closest approach to the platform, In general, there was little or no gradient in the $H_{1/3}$ values near the platform. However due to the proximity of land (1 1.5 km from the platform along the satellite's groundtrack), there are only one or two valid one-second observations after the satellite's overflight of the platform.

Two sources of $H_{1/3}$ are available at the Platform Harvest; the Nationa Data Buoy Center(NDBC) buoy 46051, San Miguel and the University of Colorado (CU) depth sensors (Kubitschek et al., this issue). The San Miguel buoy is located approximately one kilometer northwest of the platform, and provides hourly measurements of wind speed, atmospheric pressure, air and sea temperature, and $H_{1/3}$. $H_{1/3}$ is measured over a twenty minute period each hour using an accelerometer (Steele, et al., 1975), Dobson, et al. (1987) and Monaldo (1988) conclude that instrument errors in the buoy $H_{1/3}$ measurements maybe considered to be negligible. Prior to the cycle 30 overflight, this buoy failed, and so the analysis in this paper is limited to the first 29 cycles, The buoy data were interpolated to the time of the overflight, which is considered to be the time of closest approach of the satellite ground track to the platform. During most of the overflights, the CU depth sensors were put into a " highrate" mode and collected data at 1.1 second intervals. The determination of $H_{1/3}$ from these measurements is discussed in Kubitschek et al. (this issue).

3. Variations of $H_{1/3}$ with amount of data

It is usual when comparing altimeter and buoy data sets to assume that both sets of data are subsets of a larger stationary distribution. In practice, this is not strictly the case. It is not a priori clear, however, how much a collection of real world data sets such as those that exist around the altimeter overflights of Platform Harvest would deviate from such an ideal assumption. Figure 1 shows $H_{1/3}$ values calculated from the CU pressure data for time periods at increasing intervals of 3 minutes out to the maximum extent of the highrate data as normalized by the hourly value. One hour $H_{1/3}$ values are used to normalize the data sets for two reasons, First, the buoy data sets are based on twenty minutes of data every hour. Thus these data sets can be used to estimate the error generated by using only twenty minutes of data. Second, one hour of data is the amount chosen for the comparisons between altimeter $H_{1/3}$ and $H_{1/3}$ generated from the CU data. Note that when more than 40 minutes of data are included, the $H_{1/3}$ estimates are then only a weak function of the amount of data used with estimates varying by no more than $\pm 5\%$ from the hourly values.

Donelon and Pierson (1983) investigated waves in a wind-water tunnel and in a field experiment on a tower in Lake Ontario. Data were taken in conditions of nearly constant wind and fetch. They showed that estimates of $H_{1/3}$ taken over 17 minutes had an uncertainty of 12%. Both Dobson, et al. (1987) and Monaldo (1988) used these data to show that estimates of $H_{1/3}$ taken over 20 minutes had an uncertainty of 8%. The conditions at Platform Harvest were not statistically uniform, however the results shown here are consistent with the results of Donelon and Pierson. $H_{1/3}$ values based on 20 minutes of data vary by up to 4:10% from the hourly values with an rms variation of $\pm 5\%$. The hourly values vary by up to $\pm 15\%$ from $H_{1/3}$ estimates using the maximum amount of data with an rms variation of $\pm 7\%$.

4. The $H_{1/3}$ Environment at Platform Harvest

Although there was in general no high rate data taken between overflights from either the NOAA or CU systems, the NOAA systems report the sample standard deviation in addition to each six minute average. Parke and Gill (this issue) used the data around the overflight times to show that there is a linear relationship between the sample standard deviations from the NOAA acoustic system and $H_{1/3}$ determined from the CU highrate sea level data using six minutes of data, Thus the sample standard deviations from the NOAA acoustic data can be used to provide a measure of the $H_{1/3}$ distribution during the entire period. Figure 2 shows a histogram of $H_{1/3}$ inferred from the sample standard deviations of the NOAA acoustic system, From this it can be seen that $H_{1/3}$ values are are typically over 1.5 m, frequently exceed 3 m, and occasionally exceed 4 m. Figure 3 shows a histogram of $H_{1/3}$ at the overflight times based on CU depth sensor data. Note that although the mean is almost the same as that for the entire period, the extreme $H_{1/3}$ cases are missing.

5. $H_{1/3}$ Comparisons

Table 1 gives hourly $H_{1/3}$ values from the buoy, $H_{1/3}$ estimates from the CU depth sensors based on one hour of data, and $H_{1/3}$ values from the TOPEX altimeter. Comparisons between $H_{1/3}$ values from the NOAA buoy and calculated from CU highrate data are given in Figure 4, The rms difference between the two measurements is 0.27 meters with a bias of 0.11 m such that the $H_{1/3}$ estimates from CU data are lower than those from the buoy. One possible source for this bias is that the CU depth sensors cannot resolve high frequency variations (an empirical cutoff was applied between 1 cycle per 5 seconds and 1 cycle per 4 seconds). Thus the CU estimates will be low by whatever contributions were made to $H_{1/3}$

by very high frequency waves.

Figure 5 shows a comparison between $H_{1/3}$ values from the TOPEX altimeter and the NOAA buoy. There is an rms difference of 0.17m with a mean offset of 0.03m with altimeter values being larger.

Figure 6 shows a comparison between $H_{1/3}$ values from the TOPEX altimeter and the CU values. There is an rrns difference of 0.19m with a mean offset of 0.13m such that the $H_{1/3}$ values from the altimeter are higher than from the buoy. This offset is consistent with the comparison between the NOAA buoy values and the CU values, suggesting that the CU system is reading slightly low.

4. Discussion

The overflight of the ‘TOPEX/Poseidon satellite over the Platform Harvest verification site allows an excellent opportunity for comparing satellite $H_{1/3}$ measurements with nearly coincident in situ measurements. It is shown that $H_{1/3}$ estimates based on at least 40 minutes of data do not differ significantly from hourly estimates, It is also shown that, even though no criteria of statistical uniformity was imposed, results are consistent with the results of Monaldo (1988) who used the data of Donelon and Pierson (1983) to show that $H_{1/3}$ estimates based on 20 minutes of data will have an uncertainty of $\pm 8\%$.

Although $H_{1/3}$ values found at Platform Harvest only ranged between about 1.0 m and about 3.5 m at the overflight times, this covers the majority of values found in the ocean. As the histogram of $H_{1/3}$ for the ent re period shows, it is only a matter of time until more extreme conditions occur. Comparisons between the TOPEX measurements and both the NOAA buoy and CU depth sensor measurements are excellent with rms differences of 0.17m and 0.19m respectively. Despite the limited data set available at this time, these results strongly support the conclusion that the $H_{1/3}$ values obtained with the TOPEX altimeter are well within project specifications.

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Table 1: $H_{1/3}$ estimates

Cycle Number	Buoy SWH	CU SWH (1 hour)	Altimeter SWH
2	1.9	1.8	2.2
3	1.4	1.3	1.3
4	2.1	2.0	--
5	2.8	2.7	2.7
6	1.4	1.2	—
7	2.8	2.5	2,8
8	1.8	1.9	2.0
9	—	3.9	—
10	1.9	1.7	1.7
11	1.8	—	1.8
12	1.7	1.8	—
13	3.0	3.1	3.1
14	1.7	1.8	—.
15	3.0	*2.6*	*2.7*
16	3.5	3.2	--
17	2.8	—	2.8
18	1.9	—	1.9
19	2.7	2,4	2.8
20	2,5	2.7	—
21	3.4	3.6	3.5
22	1.6	1.3	1.3
23	3.2	2,8	3.2
24	1.8	1.8	2.0
25	2.3	2.7	2.5
26	1.2	1.0	1.3
27	2.5	·	2.6
28	1.6	—	1.8
29	2.6	—	2,6

Figure Captions

Figure 1: $H_{1/3}$ values as a function of the amount of time used in the calculation. All $H_{1/3}$ values are normalized by the hourly value and all calculations are centered on the respective time of overflight.

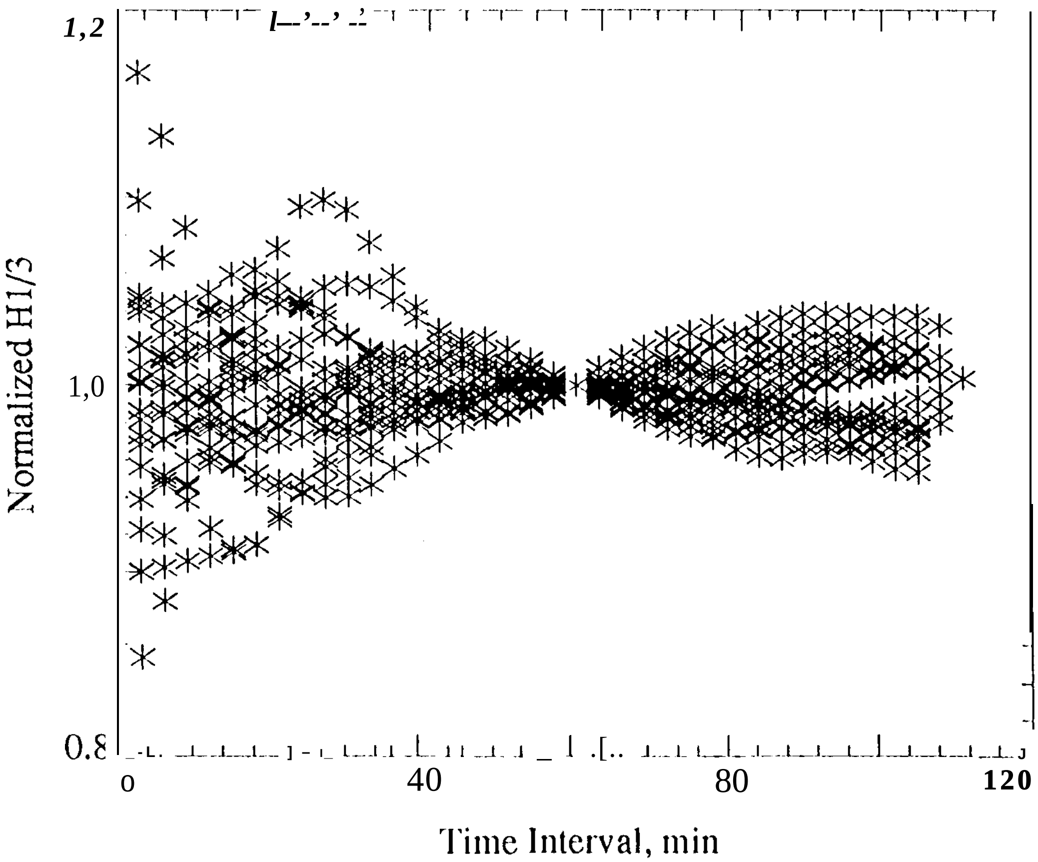
Figure 2: Histogram of $H_{1/3}$ as inferred from the sample standard deviations of the NOAA acoustic system.

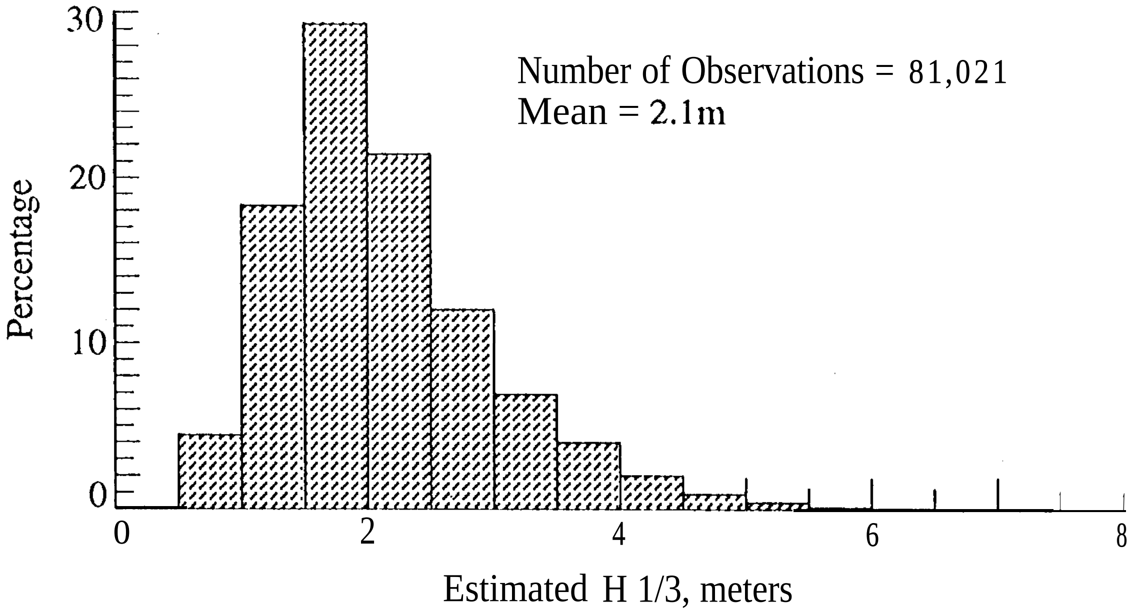
Figure 3: Histogram of $H_{1/3}$ calculated from CU 1.1 second highrate data at the satellite overflight times,

Figure 4: Comparison between $H_{1/3}$ values from the NOAA San Miguel buoy and values calculated from CU depth sensor data.

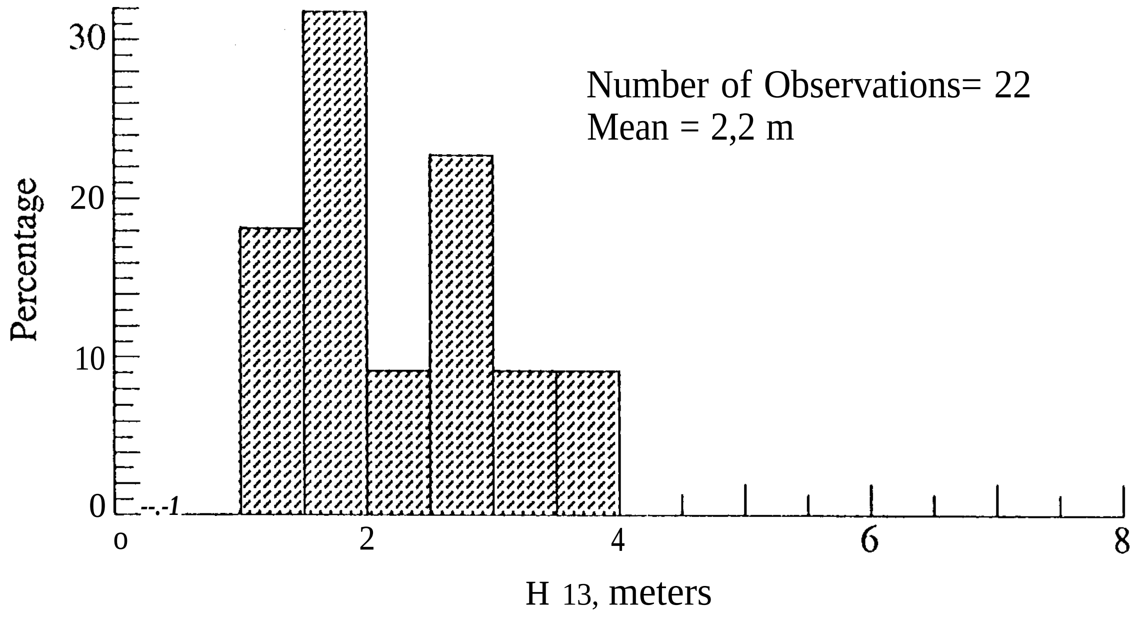
Figure 5: Comparison between $H_{1/3}$ values from the TOPEX altimeter and from the NOAA San Miguel buoy.

Figure 6: Comparison between $H_{1/3}$ values from the TOPEX altimeter and values calculated from CU depth sensor data.


1,2
1,0
0.8
Normalized H1/3
0
40
80
120
Time Interval, min



Number of Observations = 81,021
Mean = 2.1m
Percentage
30
20
10
0
0
2
4
6
8
Estimated H 1/3, meters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Mean = 2,2 m
Percentage
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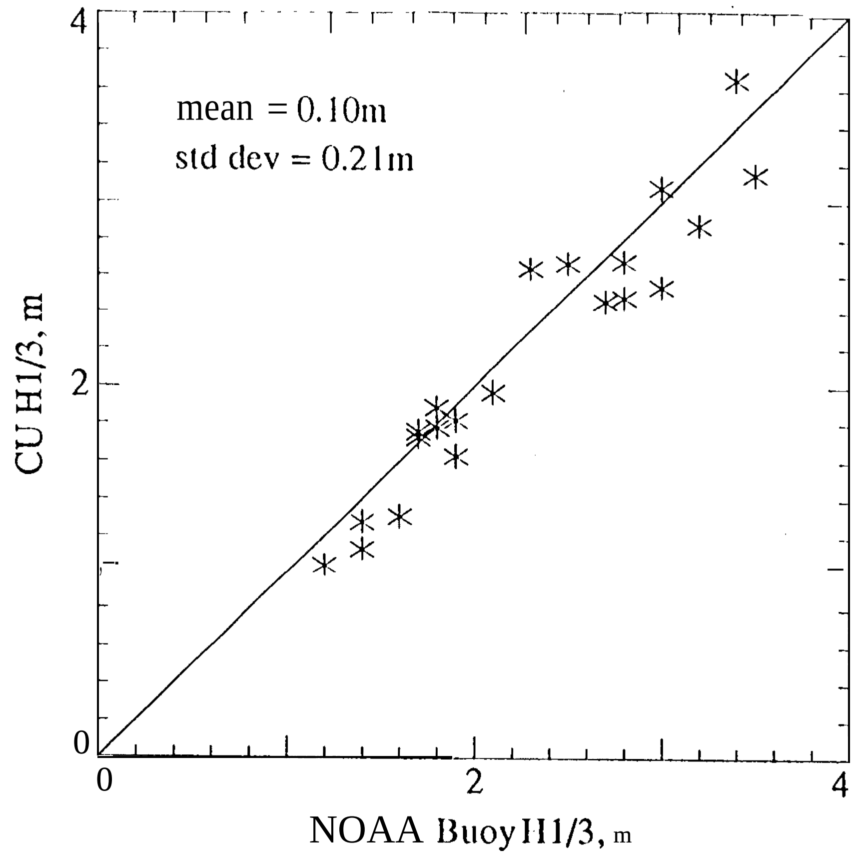
20
10
0
o
2
4
6
8
H 13, meters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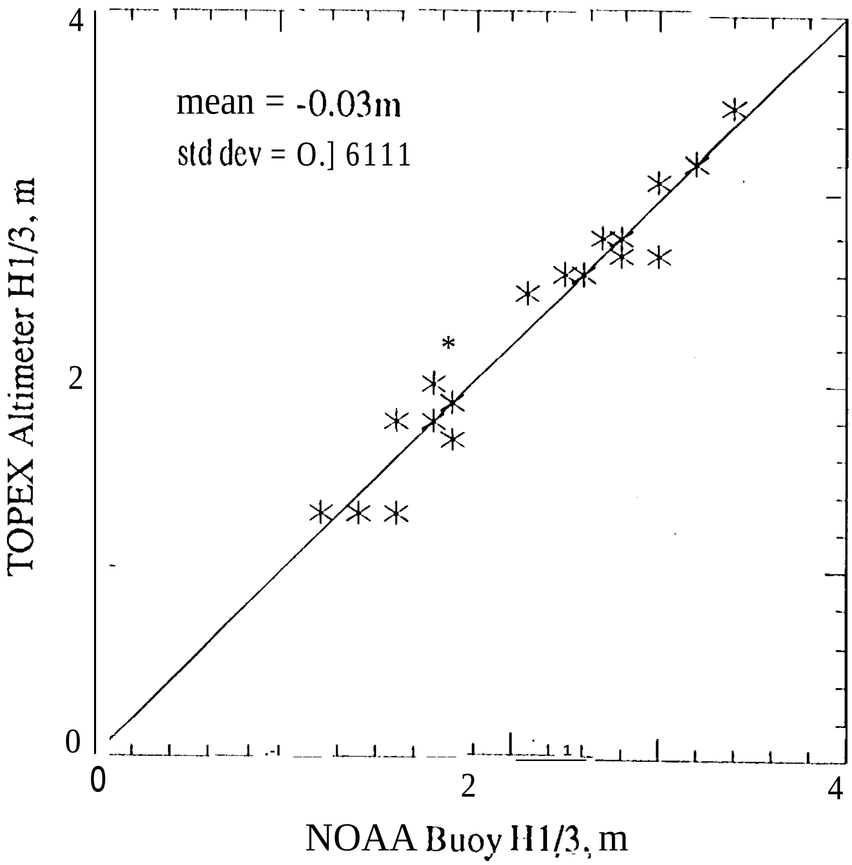
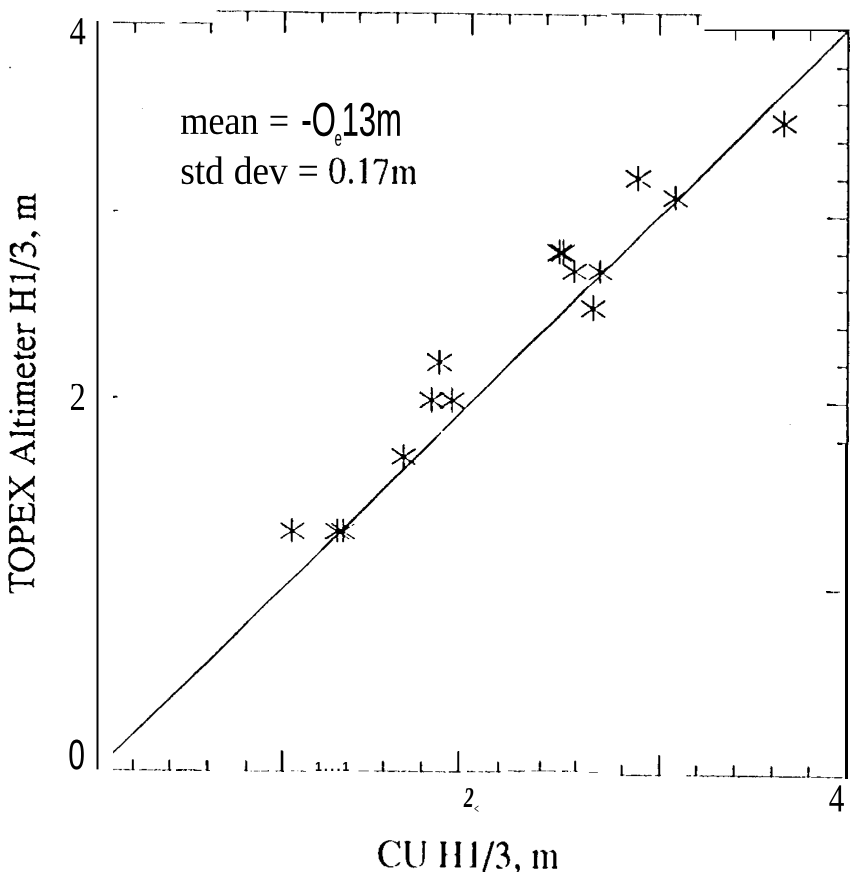
std dev = 0.21m
CU H1/3, m
NOAA Buoy H1/3, m
0
2
4
0
2
4


mean = -0.03m
std dev = 0.] 6111
TOPEX Altimeter H1/3, m
NOAA Buoy H1/3, m
0
2
4
0
2
4


mean = -0.13m
std dev = 0.17m
TOPEX Altimeter H1/3, m
CU H1/3, m
0
2
4
2
4